ON

NARCOTISM

BY THE

INHALATION OF VAPOURS.

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PART XVII.

Action of oxygen in respiration—Nature of asphyxia—Comparison between asphyxia and narcotism—Between narcotism and apoplexy—Cause of the symptoms in apoplexy — Diminished production of carbonic acid, and reduction of temperature under the influence of narcotics—Narcotic effects of cold—Colour of the blood under the influence of chloroform and ether—Irritability of the muscles after death—Effect of chloroform, &c. on this irritability, and on the rigor mortis—Modus operandi of chloroform, &c.

For a length of time after the changes which are effected in the air by respiration were discovered, it was generally believed that the carbonic acid was formed in the lungs, by the union of the oxygen of the air with carbon contained in the blood; and the phenomena of asphyxia were thought to be occasioned by the direct action of some form or combination of carbon which ought to have been excreted. Experiments by Edwards, and others, on the respiration of animals in hydrogen gas, and especially the beautiful experiments of Professor Magnus on the blood, clearly proved, however, what many physiologists had believed from the first,—that the oxygen of the air is absorbed (along with some nitrogen) and circulates with the arterial blood, combining with carbon in the systemic capillary circulation, and thus forming the carbonic acid which is exhaled from the blood in its passage through the lungs. Asphyxia is simply due to the want of oxygen in the arterial blood; for, although there is a little carbonic acid gas present in this blood during the more ordinary forms of asphyxia, yet the same symptoms occur to animals placed in hydrogen or nitrogen gas, although the carbonic acid gas in the blood is then exhaled. The presence of oxygen in the blood seems absolutely necessary to the performance of the animal functions—so necessary that none of them can continue an instant without it. Animals live, it is true, for a short time after they are deprived of air, but a little consideration shows that they live only by virtue of the oxygen which is contained in their bodies, and that when this is consumed life no longer continues. The length of time which animals live after they are deprived of air is in the inverse ratio of the activity of their functions, and Dr. W. F. Edwards has shown* that animals of cold blood, as reptiles and fishes, die of asphyxia, nearly as quickly as animals of warm blood, when they are placed in water deprived of air, and of a temperature of about 100° Fah. The increase of heat quickens the changes taking place in the body, as the same author has proved by distinct experiments: the oxygen dissolved in the fluids of the animal is soon appropriated, and life is then extinct. Animals of cold blood can also be quickly killed at the ordinary temperature by the rapid absorption of agents, such as the vapour of ether, which have the undoubted power of arresting oxidation out of the body, and when present in the blood in sufficient quantity, have the effect of preventing the oxygen it contains from any longer entering into combination. The experiments of Dr. Kay† show that venous blood has some power of supporting the functions of the brain, and the irritability of the muscles when injected into the arteries, but this depends on some free oxygen it contains; for the analyses of Magnus have proved that arterial blood is only deprived of part of its oxygen by passing once through the systemic capillaries.

The relation between asphyxia and narcotism is this—that in asphyxia there is an absence of oxygen, whilst in narcotism the oxygen is present, but is prevented from acting by the influence of the narcotic. With this close affinity between asphyxia and narcotism, as regards their intimate nature, there is, as might be expected, a great similarity in the phenomena of the two conditions. The different parts of the nervous centres lose their power, under the influence of ether and chloroform, in the

* De l'Influence des Agens Physiques sur la Vie.

† The Physiology, Pathology, and Treatment of Asphyxia, p. 193.

same order as in asphyxia. The action of the heart continues in asphyxia after the muscles of respiration have ceased to contract, and this is the case under the effects of chloroform, alcohol, ether, and probably all narcotics, when they are absorbed in a gradual and uniform manner. For, as the muscular contractions of a peristaltic character, which are under the influence of the ganglionic system of nerves, can go on with a smaller amount of oxygen than those which are dependent on the cerebro-spinal system, so it requires a larger quantity of the narcotic to arrest them. During sudden asphyxia of robust subjects by privation of air, there are generally convulsions after the loss of consciousness, and there is likewise usually an amount of muscular rigidity and contraction approaching to convulsions when insensibility is quickly induced by chloroform or ether, in muscular persons or robust animals. By gradually inducing narcotism these contractions can be avoided, and in like manner, when asphyxia is slowly induced by vitiation of a limited supply of air, convulsions are not induced. The impediment offered to the absorption of oxygen in the lungs during bronchitis is sometimes accompanied by delirium not unlike that caused by a narcotic, and occasionally coma is met with. The state of the fœtus in utero—just able to perform a few languid movements of its limbs—resembles very much the sleep caused by a narcotic. At this time it receives only a limited supply of oxygen at second hand through the placenta; but on being born, no sooner has it taken one or two free inspirations, than it exhibits an amount of activity and strength which would be fatal to the mother did it possess it whilst in the womb.

With all these points of resemblance between narcotism and asphyxia, it might perhaps be asked why a limitation of the supply of air, or in other words a partial asphyxia, might not be resorted to instead of a narcotic to prevent the pain of operations. The answer must probably be sought in the circumstance remarked by all the observers of the phenomena of asphyxia, that the blood becomes arrested at the pulmonary capillaries, when oxygen is no longer admitted into the air-cells of the lungs. On this account insensibility cannot be induced by means of asphyxia, without causing congestion of the lungs, and great distress of the respiration.

In a profound state of narcotism the symptoms often exactly resemble those of apoplexy. In both conditions there is a partial suspension of the process of oxidation on which the functions of the brain depend; but this impediment to the natural process of oxidation arises from a different cause in the two cases. In narcotism it is due to the presence of the narcotic substance in the blood, which retards oxidation, as we shall presently see, by a kind of counter affinity for the oxygen: in apoplexy it depends on more or less complete interruption to the circulation of the blood. For the constant action between the oxygen of the arterial blood and the brain, there is obviously required a never-ceasing current of blood: and when this is interrupted in any part of the brain, it is clear that there must be an interference with the process of oxidation; and it matters not whether the circulation be interfered with by pressure arising from effusion, by the occlusion of one or more of the arteries which cuts off part of the supply, or by such an amount of congestion from any cause that the current of the circulation is interrupted. According to these views it ought not to signify whether there is increased or diminished pressure in the cranium, or whether the quantity of blood in the brain is more or less than natural; but if the circulation is interrupted or greatly impeded, there ought to be the symptoms which arise from impeded oxidation. Such indeed is the fact; we meet with the same symptoms in very different physical conditions of the contents of the cranium, and the question of bleeding and the application of other remedies cannot be decided by the cerebral symptoms alone, without the consideration of other particulars.

The circulation through the capillaries of the brain is undoubtedly sometimes retarded under the influence of narcotics; but this is the consequence and not the cause of the impeded functions of the brain For, as was first pointed out by Professor Alison, the functions of the various organs of the body are accompanied by a force which aids the capillary circulation; and on the function of any organ being interrupted, the circulation through it is retarded, as s seen in the most striking manner in

the lungs during asphyxia. There is this further difference also between narcotism and apoplexy, that the narcotic acts directly on all parts of the body as well as on the brain, whilst in apoplexy the remainder of the nervous system and the other organs of the body are only effected in a secondary manner.

In my last communication,* several experiments were detailed which shew that the quantity of carbonic acid evolved from the lungs is considerably diminished under the influence of ether and chloroform. This circumstance indicates diminished oxidation, for carbonic acid is the chief product of that process in the animal frame, and it bears a pretty close relation to the amount of oxygen consumed. Dr. Prout formerly showed that the quantity of carbonic acid produced in respiration was diminished after drinking alcoholic liquors, and alcohol very much resembles ether and chloroform in chemical constitution and physiological effects. Under the influence of this agent, alcohol, Böcker ascertained, as was noticed before, that the amount of every one of the constituents of the urine is diminished, and phosphoric acid and urea are important products of oxidation.

In some experiments detailed in the first part of these papers,† the temperature of animals was seen to diminish under the continued influence of ether and chloroform. This circumstance is also illustrative of the diminished oxidation that is taking place, for the experiments of Dr. W. F. Edwards‡ on animals of various species, at different periods in their life, and in different seasons of the year, show that the consumption of oxygen in respiration always bears a direct proportion to the evolution of animal heat.§

Gradual exposure to a lower temperature, as happens in the change of season from summer to winter, alters the constitution of many animals, causing them to consume more oxygen, and thus to develope more heat, and bear up against a colder season; but other species, including some mammalia, as well as nearly all reptiles, are narcotised by the cold, and fall into a state of torpor in the winter, when the consumption of oxygen is reduced to a minimum. Cold air, or whatever abstracts the heat of the body, so as to make a considerable reduction in its temperature, is a true narcotic, and acts like other narcotics, by diminishing oxidation. Travellers in the arctic regions inform us that the symptoms produced by intense cold are sometimes not to be distinguished from intoxication by alcohol, except by the circumstance that no spirituous liquors can have been obtained. As regards its local effects, cold is probably the narcotic which has been longest known to the human species; for its benumbing effects (ναρκόω, I benumb) make themselves felt, in the fingers at least, in most parts of the earth, at some season of the year. The local application of cold closely resembles that of chloroform and many other narcotics, in causing a slight amount of pain before sensibility is altogether abolished. Dr. James Arnott, who has given great attention to the local effects of graduated temperature in the treatment of various affections, has relieved neuralgic pains by the application of a mixture of salt and pounded ice, and has also rendered the surface of the body so insensible, that the introduction of setons, and other operations of a superficial nature, have been performed without pain. Dr. Arnott calls the process congelation; but the hardness which is produced in the part must depend on the solidification of the adipose substance; for if the water which enters into the composition of the tissues were frozen, their intimate structure would be destroyed, and a slough would be the result.

The effects of ether and chloroform on the appearance of the blood agree perfectly with the view above given of their modus operandi. There is generally no alteration in the complexion of the patient, or in the colour of the mixed venous and arterial blood as it

* See last vol. p. 622.

† Medical Gazette, vol. xli. p. 850.

‡ Op. cit.

§ The cooling of animals, in Sir B. Brodie's experiments, when the circulation was kept up by artificial respiration, after they were reduced to a state of suspended animation by narcotics, gives support to the above views, allowance being made for the artificial condition of the animals. The other experiments of this eminent physiologist, in which animals were found to cool rapidly under similar circumstances, after removal of the brain, are not at all opposed to the view that animal heat results from the process of respiration, if we reflect that respiration, or oxidation, is essential to all the animal functions, and that the formation of phosphoric acid and urea are probably as much accompanied by the evolution of caloric, as is the formation of carbonic acid.

flows from a wound, so long as the inhalation is not pushed to the extent of embarrassing the respiration, and provided the patient is not holding his breath, on account of the pungency of the vapour, or a general state of rigidity which sometimes occurs for a minute or two; but when the blood which flows from the arteries and veins can be separately observed, whilst the patient is well under the influence of the narcotic, it is seen that the arterial blood is somewhat less florid, and the venous blood less dark than under ordinary circumstances. The lighter colour of the venous blood, which has been spoken of by Dr Gull, as well as by myself, points particularly to a diminution of oxidation in the systemic capillaries.

The phenomena attending the irritability which remains in the muscles for a longer or shorter time after death, and particularly the effect of narcotics on this irritability, accord exactly with the views above expressed. It can be shown, by the following amongst other reasons, that the muscular irritability depends on a little oxygen still remaining in the blood contained in the muscular tissue. Nysten* found that the injection of oxygen gas into the cavities of the heart increased the vigour and duration of the contractions. Sir B. Brodie states that, in dogs in which the circulation was kept up after death by artificial respiration, "there seemed to be actually an increased irritability of the voluntary muscles, continued not for a short time, but even for an hour and a half."† Nysten informs us‡ that the general result of his observations on the duration of the muscular irritability in animals of different classes, and of different orders of the same class, was in the inverse ratio of the muscular energy developed during life; and we previously saw, on the authority of Edwards, that this was just the ratio of duration of life under privation of air or asphyxia.

Chloroform, ether, alcohol, and probably all narcotics, have the power of suspending the muscular irritability. In a former paper of this series§ some experiments were related in which the irritability of the heart in frogs and rabbits was removed by the vapour of chloroform; and in two of the experiments the irritability was alternately allowed to recover by letting the chloroform evaporate, and then suspended again by a fresh exposure to the vapour. In one of these experiments the peristaltic action of the small intestine of a rabbit was arrested by the local action of chloroform. I have frequently stopped the quivering motion of the intercostal muscles, which is seen on opening the chest of an animal immediately after death, by blowing a little vapour of chloroform on them through a tube. On one of these occasions Dr. Sibson was present.

The following experiments show the action of chloroform, &c., on all the muscles of the body:—

Exp. 80.—A half-grown guinea-pig was made to inhale chloroform in a glass jar till it ceased to breathe. The chest was then opened, and a tube armed with a stop-cock was introduced into the aorta and tied. The heart was still contracting, and the muscles were very sensible to the shocks of an electro-magnetic apparatus. Fifteen minims of chloroform, and two drachms of tepid water, which had been agitated together till the chloroform was suspended in minutes globules, were now injected. At the moment of injection the right anterior extremity and the two posterior extremities were stretched out, and the toes quivered. These limbs became quite rigid at the moment of the injection, as did also the neck and trunk of the animal. The left anterior extremity remained flexible. The wires of the battery were applied to the muscles of various parts of the body immediately after the injection, but no contractions could be excited, except in the left anterior extremity, and the muscles of the chest on the same side, which remained as irritable as before; the reason of this being that the injection had not entered the left subclavian artery. The heart ceased to act at the moment of the injection, and was afterwards quite insensible to the shocks of the battery.

Exp. 81.—A similar guinea-pig to the last was killed by the inhalation of ether, and was opened immediately after it ceased to breathe, whilst the heart was still acting. The tube was secured in the descending aorta, and two fluid drachms of sulphuric ether were injected. The posterior extremities were stretched

* Recherches Physiologiques, p. 335.
† Physiological Researches, 1851, p. 108.
‡ Opus cit. p. 355.
§ Vol. xlii. p. 415, 614.

out at the time of the injection, and there was a quivering motion of the toes. These extremities, together with the posterior half of the trunk, became instantly affected with post-mortem rigidity, and were totally insensible to the shocks of the electro-magnetic battery. The anterior extremities, and, indeed, all the anterior part of the body which had not been injected with ether, remained sensible to the shocks of the battery, and only became rigid between two and three hours after death. The heart ceased to act at the moment of the injection, some ether having been dropped on it from the syringe.

Exp. 82.—An ounce of rectified spirit of wine was injected into the aorta of a cat immediately after death from chloroform. There were muscular contractions at the moment of injection, but no contractions could be excited afterwards by mechanical irritation, although the muscles were very irritable just before, and were quivering when not touched. The heart, which was previously beating, also ceased to act. Post-mortem rigidity began to take place five minutes after the injection, and it still existed eight days afterwards.

Exp. 83.—A cat was killed by inhalation of chloroform, and three minutes after death three drachms of rectified spirit of wine, of 80 per cent., were mixed with three drachms of water, and injected into the descending aorta. The posterior extremities were stretched out at the moment of the injection, and almost immediately began to be rigid; and in less than ten minutes after the injection, the whole of the posterior half of the body was very rigid, whilst the anterior parts were quite flexible. An hour after death rigidity was commencing in the anterior extremities, and in half an hour more they and the neck were quite rigid. This cat was killed on Dec. 1st, 1850, and was kept in a room with a fire. The rigidity of the anterior half of the body began to subside at the end of a week, but that of the posterior extremities not till a fortnight had elapsed; and they were still quite fresh, although putrefaction was commencing in the chest and neck.

As absorption of vapour continues in the frog by its skin after the respiratory movements have ceased, it is not necessary to resort either to dissection or injection in them, as in mammalia, in order to cause the extinction of irritability, and bring on the post-mortem rigidity. It can be induced in a very few minutes by exposure to the vapour of ether or chloroform, although, under ordinary circumstances, the muscles remain long irritable and flexible in these animals. In some interesting experiments lately detailed in the Medical Gazette by Mr. W. F. Barlow,* that gentleman produced rigidity in a single limb of living frogs without much affecting the rest of the animal; he also observed what I had previously remarked,† that the setting in of rigidity in these animals is sometimes accompanied by a movement of the body.

The state which is called post-mortem rigidity appears to be the natural condition of muscle when no kind of change in its composition is taking place. As long as the feeble oxidation continues, which enables it to be irritable after death, it remains flaccid; but when this ceases, from want of oxygen, from reduction of temperature, from the counter affinity of a narcotic, or from exhaustion of the nutrient materials, the muscle becomes rigid, and remains so till a new kind of oxidation—that of putrefaction—commences, when it again becomes flaccid. Although the muscles, when affected with this kind of rigidity, are in a state of completely suspended animation, they are not always incapable of again living; for M. Brown Sequard has restored the irritability of the muscles of a dead guinea pig after they had been rigid from ten to twenty minutes, by making the blood of a living animal of the same species circulate in its vessels. Although reducing the temperature hastens rigidity, it is not essential to it; for I have seen a fœtus at the full term born in a state of complete rigor mortis.

In a former paper‡ several proofs were given that chloroform and ether do not prevent oxidation in the system by themselves combining with the oxygen of the blood. Among these proofs were some experiments showing that the chloroform and ether are exhaled again unchanged from the blood as it circulates through the lungs. The paper of next week will contain an inquiry into the manner in which these narcotics act in limiting and preventing oxidation in the living frame.

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* Page 713.

† Med. Gaz., vol. xlii. p. 415.

PART XVIII.

Antiseptic power of narcotics—Narcotic vapours and gases prevent ordinary combustion—They prevent the slow combustion of hydrogen by means of spongy platinum—They prevent the oxidation of phosphorus—Nature of the power by which narcotics prevent oxidation in the living body and out of it—Recapitulation.

During the last two years, whilst the investigations which I have been making respecting chloroform and ether, and publishing from time to time in the Medical Gazette, have been directed more particularly to showing the *modus operandi* of these agents, M. Robin, of Paris, has been engaged in a like inquiry, and has arrived at similar conclusions, although his researches have been made in a different manner. His opinion was given at the Academy of Sciences to the following effect:—That the anæsthetic action of the vapour of ether or chloroform is the result of a state of asphyxia more or less complete; but that this kind of asphyxia is produced by these agents, when absorbed, protecting the blood in the capillary vessels against the action of the oxygen, in the same way that they protect a piece of flesh, or any other animal substance that is plunged into them, against the action of the same agent, oxygen, and thus prevent putrefaction.* M. Robin subsequently gave his views to the Academy in a more extended form. He stated that all substances which will preserve dead animal and vegetable matters against putrefaction are capable of acting as poisons to all organised beings, whether possessed of a nervous system or not; that the action is independent of their coagulating or not coagulating albumen; and that it consists in the power they have of protecting organised matters from slow combustion by moist oxygen. He stated that they diminish or completely interrupt the combustion according to the quantity; and that, in proportion to the dose, they are sedative medicines to animals, and asphyxiating poisons to all organised beings.*

The following are amongst the substances enumerated by M. Robin as having the properties in question:—Sulphuric ether, chloroform, benzin, Dutch liquid, hydriodic ether, acetic ether, naphtha, sulphuret of carbon, camphor, protochloride of carbon, carburet of nitrogen, hydrocyanic acid, and arsenic. The first seven of the above agents are amongst those whose narcotic effects I have described in the Medical Gazette.

The antiseptic power of these and other substances is probably in direct proportion to their narcotic strength; at all events, I have ascertained that such is the case as regards chloroform, ether, and alcohol. A few drops of chloroform, when put into a bottle, form enough vapour to prevent putrefaction in a piece of flesh suspended in it; but it requires a larger quantity of ether, which is a less powerful narcotic, to produce a like effect. One part of ether, when mixed with nine or ten parts of water, preserves animal matters; but a larger proportion of alcohol is required for a like effect; and alcohol, as is well known, requires to be taken in much larger quantity than ether to cause insensibility. I have often observed the antiseptic powers of chloroform, even in the small quantity which suffices to cause the death of an animal, especially when it has been inhaled slowly, so that the tissues were intimately impregnated with it. For instance, the cat which formed the subject of Experiment 73 in a former paper,

* See Comptes Rendus, t. xxx. p. 52.

* Comptes Rendus, t. xxxi p. 383; and Med. Gaz. vol. xlvi. p. 590.

and which was killed with chloroform, was kept for sixteen days in a temperature between 50° and 60° Fahr., and, at the end of that time, the rigor mortis was only beginning to subside, and putrefaction had scarcely commenced.*

The substances which have the property of limiting and preventing oxidation in the living body, have also the property of limiting and preventing that kind of oxidation which constitutes ordinary combustion. If, for instance, as much ether as will make not less than about eight cubic inches of vapour be diffused through the air of a bottle or jar holding one hundred cubic inches, and a lighted taper be lowered into the vessel, it will be extinguished. The vapour of ether will take fire at the mouth of the bottle; but the taper will go out as it descends into the air mixed with vapour not in a state of combustion. Flame is extinguished also by the vapour of chloroform when in sufficient quantity, and by many other vapours and gases. Sir Humphry Davy, whose investigations on flame resulted in the discovery of the safety-lamp, thought at first that the power of preventing combustion in these instances depended on the cooling power of the gas employed as a diluent; but, on making experiments with various gases, he found that some other cause or causes existed. Olefiant gas had a much greater effect in preventing the explosion of oxygen and hydrogen by the electric spark than any of the other gases employed by Sir H. Davy, and this gas is a more powerful narcotic than carbonic acid, or any of the others he used, except sulphuretted hydrogen (which probably acts in a different manner from ordinary narcotics), for I have found that olefiant gas causes immediate insensibility in birds, when mixed with the air in the proportion of one part to ten.

Dr. Henry, and Professor Graham,* have ascertained that a number of gases have the effect of preventing the slow combination which takes place between oxygen and hydrogen with the aid of spongy platinum, and that the relative power of the various gases is nearly the same in this instance as when the electric spark is employed, olefiant gas being the most powerful.

Professor Graham discovered† that a number of vapours, as well as gases, have the property, when mixed with atmospheric air, of preventing the slow oxidation of phosphorus, which renders it luminous in the dark. He found that olefiant gas, and the vapour of oil of turpentine, and of other essential oils, possess this power, even when present in a very minute quantity. I expressed an opinion nearly five years ago,‡ that the action of ether on the human frame was of the same kind as that by which it prevented the oxidation of phosphorus; and this view is supported by the fact, that amongst substances of a similar constitution, whose narcotic power is known, this power bears a direct relation to the power of preventing the oxidation of phosphorus. For example, I find that the vapour of alcohol has but little influence in this respect, whilst Prof. Graham found that the vapour of ether, in the proportion of one part to 150 of air, prevents the oxidation of phosphorus at all temperatures up to 64° Faht.; that one part of olefiant gas (which is a more powerful narcotic) has a like effect in 450 parts of air; and that one part of vapour of naphtha exerts this influence when diluted with 1820 parts of air. Now naphtha consists chiefly of benzin, which, as was stated in a former paper, causes insensibility when less than a grain of it it diffused in each hundred cubic inches of the

* I am persuaded that the antiseptic properties of various substances are capable of producing greater advantages than they have hitherto, especially if applied by the method of injecting the arteries immediately after death, which was described in my last paper. Owing to the difficulty of curing meat by the ordinary methods in tropical climates, thousands of oxen and sheep are slaughtered in South America and Australia, for the tallow and hides, whilst the flesh is left to rot; when, by injecting the vessels, it could be immediately rendered as firm as in the coldest climate. There would probably be a prejudice against using a medicine such as chloroform for this purpose; but it fortunately happens that the essential oils, which exist in nearly all condiments, are both narcotic and antiseptic. I have frequently made insects insensible by exposing them in a covered vessel to the vapour of oil of peppermint; and, on one occasion, I rendered a linnet insensible by the inhalation of the vapour of oil of lemons: by injecting twenty minims only of the latter essential oil (shaken up with an ounce of water) into the arteries of a rabbit after death, it kept very well for seventeen days. I have found that injecting with a saturated solution of common salt very much hastens rigidity, although it does not produce it immediately. I hope that some one who has the opportunity will follow up this subject, as it promises to yield a kind of wealth more useful than the newly-discovered treasures of California and Australia.

* Quarterly Jour. of Sc., 1829, part ii. p. 354.
† Op. cit.
‡ See MED. GAZ., vol. xxxix. p. 383.

respired air. Professor Graham ascertained that hydrochloric acid gas promotes the oxidation of phosphorus in the air; and I find that the vapour of chloroform does not prevent it: this is probably due to the chlorine it contains in such large quantity.

Professor Graham states that olefiant gas prevents phosphorus and hydrogen from uniting with oxygen without undergoing any change itself. This is exactly analogous to the action of ether and chloroform in the human body, which, as shown before, produce their effects, and pass off unchanged in the expired air.

Having traced the narcotic action of ether and other bodies to the more general law of their power of preventing oxidation under a great variety of circumstances, the mind naturally inquires by what kind of power oxidation is thus prevented. I feel considerable diffidence in offering a theory on a subject which falls as much within the domain of ordinary chemistry, as within that of physiology, when so eminent a chemist as Professor Graham has investigated a number of its details without suggesting any general explanation on the matter. However, as I have formed a theory in my own mind, I offer it for consideration: it is to the following effect:—That chemical attraction or affinity is a constantly acting force, by which each atom of matter exerts an influence on all other atoms within the sphere of its attraction, whether they are of the same or of a different kind, the force of the attraction varying with the respective nature of the substances, and the physical conditions in which they are placed. In this point of view, it will be seen that any two substances in a condition to unite together might be prevented from doing so by the intervention of a third body possessing a sufficient attraction for either of the others; and it would not be necessary that this third body should itself enter into chemical combination; for a balance of forces might be established, so that the three substances would remain exerting reciprocal attractions for each other, but unable to enter into more intimate union.

In the instances of prevented oxidation previously considered, the interfering substances no doubt owe their influence to their attraction for oxygen. These substances, in fact, are known to possess a strong affinity for oxygen, being nearly all of them highly combustible. Those of them which have the greatest power in preventing oxidation—as olefiant gas and benzin—contain no oxygen in their composition; whilst the oxide of ethyle, which contains rather more than one fifth of its weight of oxygen, has less power; and alcohol, which consists of oxygen to the extent of rather more than one-third, has much less power than ether as a narcotic, as an antiseptic, and in preventing the oxidation of phosphorus. The salts of ethyle, without oxygen, produce narcotic effects also in much smaller doses than its oxygen salts. It was previously shown that the narcotic powers of the ethers and other allied agents was in the inverse ratio of their solubility in water,—a generalization which is in perfect accordance with what is now stated; for it so happens that the agents of this class which contain oxygen are more soluble than those which do not.

As regards their application to the substances when acting as narcotics, the views just explained may be thus briefly stated. When absorbed into the blood, they have an attraction for the oxygen dissolved in it; and though unable to combine with the oxygen under the circumstances, the attraction is sufficient to counteract that existing between the oxygen, on the one hand, and certain constituents of the blood and tissues of the organs, on the other; and thus the combinations between the respired oxygen and the materials of the body—those changes which are, in a manner, the essence of all the animal functions—are prevented more or less completely, according to the dose of the narcotic.

There is a curious circumstance connected with the oxidation of phosphorus, to which it is necessary to allude. Professor Graham found that pure oxygen has no action on phosphorus under the atmospheric pressure, at temperatures below 64°; but that a slight expansion of the gas, by diminishing the pressure two or three inches, or diluting the oxygen with nitrogen, hydrogen, or certain other gases, enables it to act on the phosphorus, which then becomes luminous in the dark. The explanation I would offer of this circumstance is, that the attraction or affinity of the atoms of oxygen for each other is sufficient to

prevent their combining with the phosphorus until that attraction is weakened by their separation to a greater distance by the diminution of the pressure or the intervention of tho atoms of another gas.

In dismissing this part of the subject I should like to remark, that whatever may be thought of the above explanation of the power by which certain narcotics retard or arrest oxidation in the animal frame, will not affect the fact of these narcotics acting in this way, for it rests on distinct evidence previously stated.

I have said nothing of the stimulant or irritant properties which chloroform, ether, alcohol, and probably all narcotics, possess in a greater or less degree, and I have not space to enter on that subject; but I expect to be able to show on another occasion, that the irritation caused by narcotics is not opposed to the view of their acting in the way explained in the previous pages.

These papers on narcotism by the inhalation of vapours have extended over a very much longer time than I expected, and I have done after all much less than I intended. In now bringing them to a close, however, it may be well to give a brief recapitulation of the more prominent points which I have endeavoured to establish.

Several experiments with chloroform and ether were described, the object of which was to determine the quantity of these agents which exists in the blood in a state of insensibility. The method employed was that of placing a small animal in a large vessel, containing a known quantity of vapour mixed with the air, and allowing it to remain till the effects of the vapour no longer increased, but became stationary; when, the solubility of the vapour in the serum of the blood being known, the quantity absorbed could be calculated from the relative saturation of the air. It was found that, with both chloroform and ether, the proportion, in a state of complete insensibility, was about one twenty-eighth part as much as the blood would dissolve. Similar experiments were made with several other substances, including some salts of ethyle, benzin, bromoform, Dutch liquid, and sulphuret of carbon, and it was found that tho proportion absorbed into the blood, in causing insensibility, was nearly the same as in the case of ether or chloroform. Hence the rule was deduced, that the narcotic strength of these substances was in the inverse ratio of their solubility. The agents to which this rule applies resemble chloroform and ether in containing carbon, and not containing any nitrogen as a radical elemont, and some of them were used as was described with success, in preventing the pain of surgical operations.

A description of the influence of chloroform was given, in which tho effects it produces, if continued until respiration is suspended, were divided into five degrees. It was stated that when chloroform is given to animals neither very quickly nor slowly, and continued till the breathing is arrested, the heart continues to beat; but some experiments were detailed which show that chloroform is capable of arresting the action of the heart, if absorbed in sufficient quantity.

The cases of accident from inhalation of chloroform, which had happened up to the time of writing, were next considered, when it appeared that the fatal event in these cases was due to the vapour of chloroform being given in too concentrated a form, by which not only was the breathing suddenly arrested, but the action of the heart was also paralysed by the effect of the vapour.*

The opinion was expressed that chloroform, if given gradually and with due care, may be safely employed in every case in which a surgical operation has to be performed; an opinion in which I have been altogether confirmed by further experience.

Directions were next given for the administration of chloroform in various kinds of operations; the conditions and diatheses which influence its action were considered, and a numerical result of the larger operations in which I had administered chloroform or ether at that

* The fatal cases which have since happened, together with some that narrowly escaped being fatal, entirely confirm the opinion then expressed. The alarming symptoms always came on in the most sudden manner, the action of the heart being suspended without previous warning, although in some of the cases there had been at first an apparent difficulty in rendering the patient insensible. No means were used in any of these cases to insure a proper dilution of the vapour with air, a handkerchief being merely employed for administering chloroform, except I believe in one case, where it was not administered by a medical man.

time was given, by which it was shown that the result had been favourable.

After some remarks on the use of Dutch liquid in operations and midwifery, some experiments with alcohol were detailed, by which it was shown to resemble ether and chloroform in its effects and mode of action. Experiments were related showing that chloroform passes off unchanged in the expired air; that it can be detected in limbs amputated whilst patients are inhaling, and also in the dead bodies of animals killed by it. It was next shown that ether and alcohol can be detected in the expired air, and that the quantity of carbonic acid excreted by the lungs is diminished under the influence of chloroform and ether. For these and other reasons the conclusion was arrived at, that the class of narcotics we have been considering, and probably other narcotics also, produce their effects by virtue of a power they possess of retarding the action of the respired oxygen on the blood and tissues of the body.

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